

Binary Black Holes, Accretion Disks and Relativistic Jets: Photocenters of Nearby AGN and Quasars

Principal Investigator: Ann E. Wehrle (Interferometry Science Center/JPL/Caltech)

Team Members:

Dayton L. Jones (JPL), David L. Meier (JPL), B. Glenn Piner (Whittier College),
Stephen C. Unwin (JPL)

One of the most challenging questions in astronomy today is to understand the origin, structure, and evolution of the ‘central engines’ in the nuclei of quasars and active galaxies (AGNs). The favoured theory involves the activation of relativistic jets from the fueling of a supermassive black hole through an accretion disk. In some AGN an outer optically thick, ‘dusty torus’ is seen orbiting the black hole system. This torus is probably related to an inner accretion disk - black hole system that forms the actual powerhouse of the AGN. In radio-loud AGN two oppositely-directed radio jets are ejected perpendicular to the torus/disk system.

Although there is a wealth of observational data on AGN, some very basic questions have not been definitively answered. The Space Interferometry Mission (SIM) will address the following three key questions about AGN.

1. Does the most compact optical emission from an AGN come from an accretion disk or from a relativistic jet?
2. Does the separation of the radio core and optical photocenter of the quasars used for the reference frame tie, change on the timescales of their photometric variability, or is the separation stable at the level of a few microarcseconds?
3. Do the cores of galaxies harbour binary supermassive black holes remaining from galaxy mergers? It is not known whether such mergers are common, and whether binaries would persist for a significant time.

Astrometry of quasars The SIM fringe spacing is ≈ 10 milliarcseconds (mas), so most AGN cores will be unresolved. However, with global astrometry, radio (ICRF) and optical (SIM) positions of radio-loud quasars can be compared at the sub-milliarcsecond level. Changes in the optical positions over the course of the mission will be resolvable by SIM at the few μ as level. Such changes may be caused by motion of relativistically beamed features in a jet. In addition to absolute astrometry, SIM will allow differential astrometry – color-dependent position shifts – across the optical waveband. This will prove to be a powerful diagnostic tool for AGN structure on scales of a few μ as.

Testing AGN models using astrometry SIM should be able to distinguish which of the AGN emission regions (sketched in Figure 1, for the size scales relevant to SIM) dominates. We use SIM’s ability to measure any shift in the optical photocenter of AGN emission as a function of colour. We identify two distinct possible locations for the photocenter of the red light relative to the blue. In both cases, most of the blue light is thermal emission from the optically thick part of the accretion disk – the ‘Big Blue Bump’.

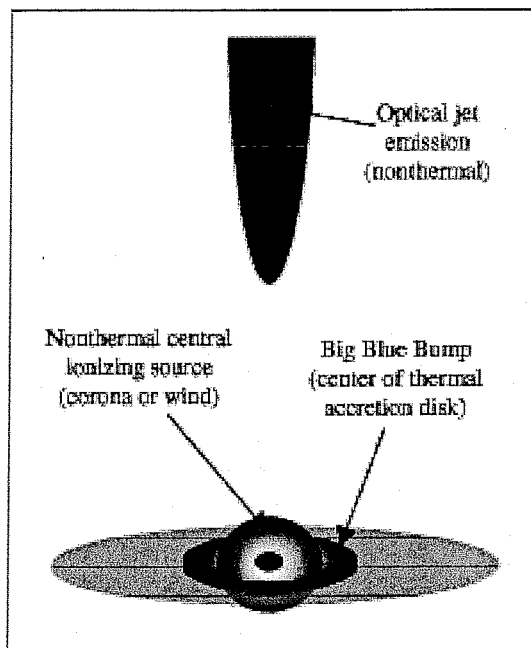


Figure 1: Schematic model of the central ionizing source (after Band & Malkan 1989) and jet (after Königl 1981) for a typical AGN. Size of the central disk/corona structure is $\sim 70 - 120 R_{\text{Sch}}$ ($\sim 100 - 160 \mu\text{as}$ for M87, or only $1 - 2 \mu\text{as}$ for a typical quasar at a redshift of 0.5). The offset between the optical jet and disk emission for 3C 345 at $z = 0.6$, based on the Königl model, is expected to be $\sim 0.4 \text{ pc}$ or $80 \mu\text{as}$.

Case 1. Most of the red light is power-law synchrotron emission along the relativistic jet. The red photocenter will be offset along the VLBI jet direction from the blue photocenter associated with the accretion disk.

Case 2. The red light comes from synchrotron or inverse Compton emission from a hot, magnetized corona or wind above the accretion disk. The red and blue photocenters should be coincident.

Example: Nearby radio galaxy M87. We expect the optical emission to be dominated by the accretion disk region because its jets are not pointing within a few degrees to our line of sight (Biretta *et al.* 1991). There should be no colour shift between the red and blue SIM bands, because the corona and accretion disk are axisymmetric (Figure 1). However, we expect a relatively large offset (as large as several $100 \mu\text{as}$) between the optical photocenter and radio photocenter (which is dominated by emission from the optically thick base of the radio jet).

Binary Black Holes Do the cores of galaxies harbour binary supermassive black holes remaining from galaxy mergers? How commonly does this occur? This is a question of central importance to understanding the onset and evolution of non-thermal activity in galactic nuclei. An entire AGN black hole system may be in orbit about another similar system, as might occur near the end of a galactic merger, when the two galactic nuclei themselves merge, with a characteristic timescale is a few hundred million years. How large is the astrometric signature? Rough

estimates, based on the circumstantial evidence currently available, indicate that displacements of $10 \mu\text{as}$ or more (readily detectable with SIM) may be present in a number of AGN. The best candidate is probably OJ 287 (Lehto & Valtonen 1996; Kidger 2000), with an inferred period of 24 years from variability monitoring, and a mass of 10^9 solar masses. During 5 years of SIM monitoring, the expected orbital displacement is about $15 \mu\text{as}$.